



Advanced Simulation: A Critical Tool for Future Nuclear Fuel Cycles

Advance Fuel Matrix For Next Generation Reactors

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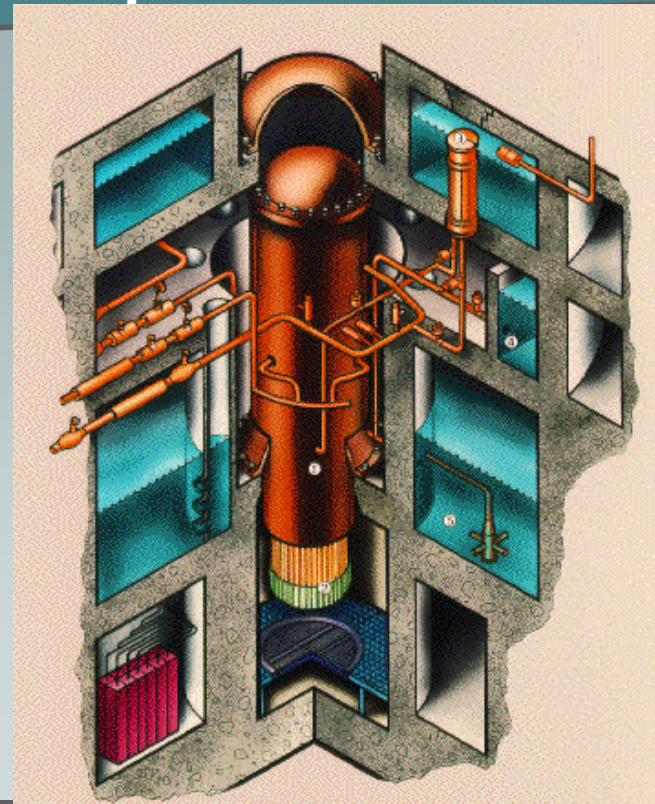
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Computational Studies of Nuclear Power System

Power Plant Core Components

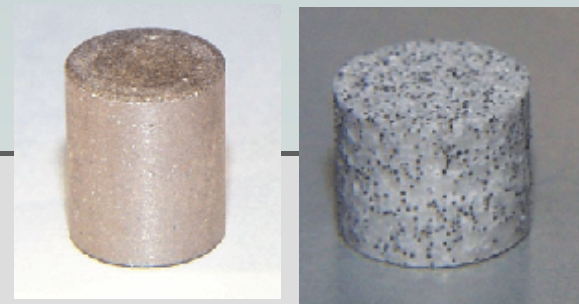
- ▶ Structural Mechanics
- ▶ Neutronics
- ▶ Thermal Hydraulics
- ▶ **Fuel Behavior**
 - Theoretical Estimates
 - Validation



Advance Fuel Matrices

Fuel Forms

- ▶ Oxides, Nitrides & Carbides
- ▶ Mix-Oxides (MOX)
- ▶ Composites
- ▶ Inert Matrix (ZrO-MgO + Pu)
- ▶ TRISO
- ▶ Metals



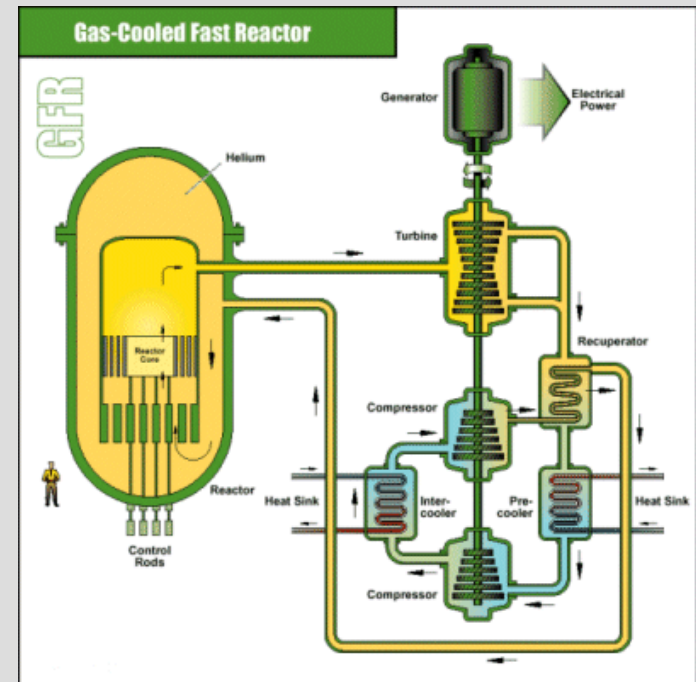
Characteristics of Next Generation Reactors

► Gas-Cooled Fast Reactor

- Helium Coolant
- 850°C; 288 MWe
- Direct Gas Turbine
- Waste Minimization & Effective Use of U Resources

► Fuel Characteristics

- Potential to Operate at High Temperatures
- Excellent Retention of Fission Products
- Composite Ceramic Fuel
- Advanced Fuel Particles
- Ceramic-Clad Elements of Actinide Compounds

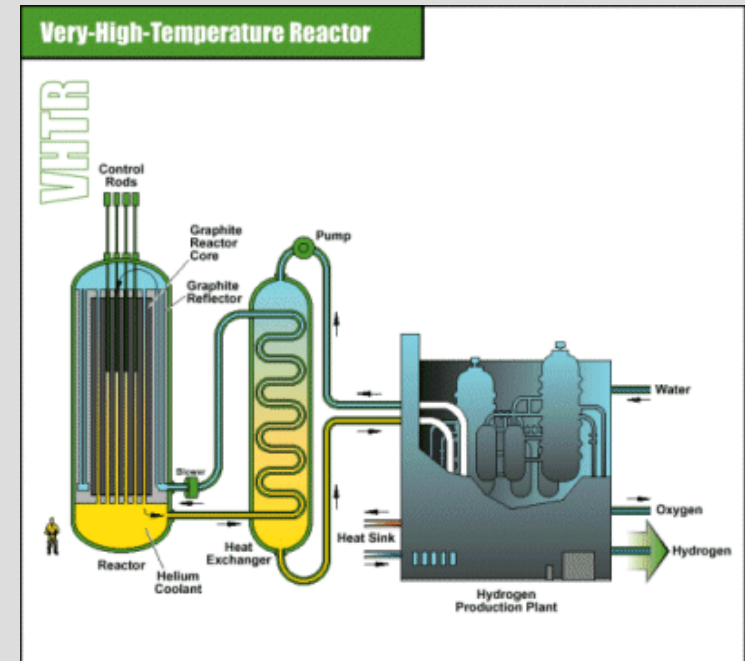


Characteristics of Next Generation Reactors

- ▶ Very High Temperature Reactor (VHTR)
 - Helium Coolant
 - 1000°C; 600 MWth
 - Waste Minimization & Effective Use of U Resources

▶ Fuel Characteristics

- Potential to Operate at High Temperatures
- Excellent Retention of Fission Products
- TRISO
- Advanced Fuel Particles
- Ceramic Clad Elements of Actinide Compounds



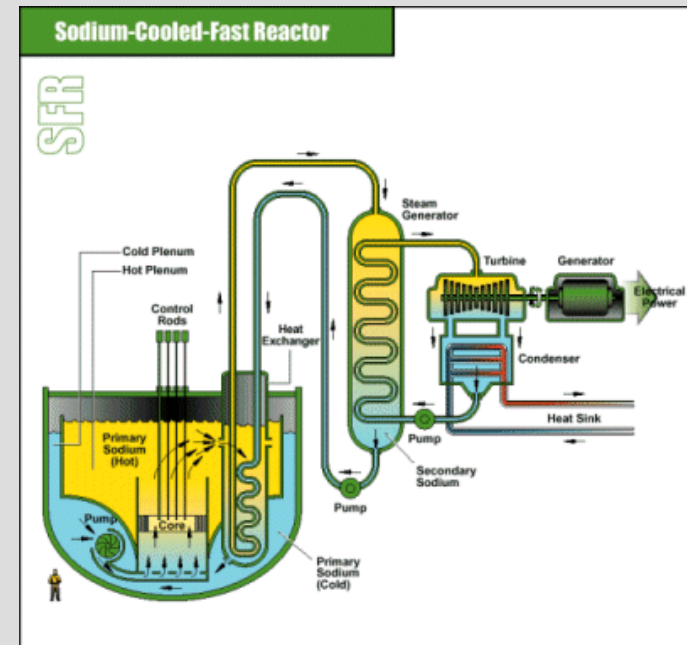
Characteristics of Next Generation Reactors

► Sodium-Cooled Fast Reactor

- 550°C; 500 to 1500 MWe
- Efficient Management of Actinides and Conversion of Fertile Uranium

► Fuel Characteristics

- Uranium-Plutonium-Minor Actinide-Zirconium Metal Alloy Fuel
- Composite Ceramic Fuel
- MOX



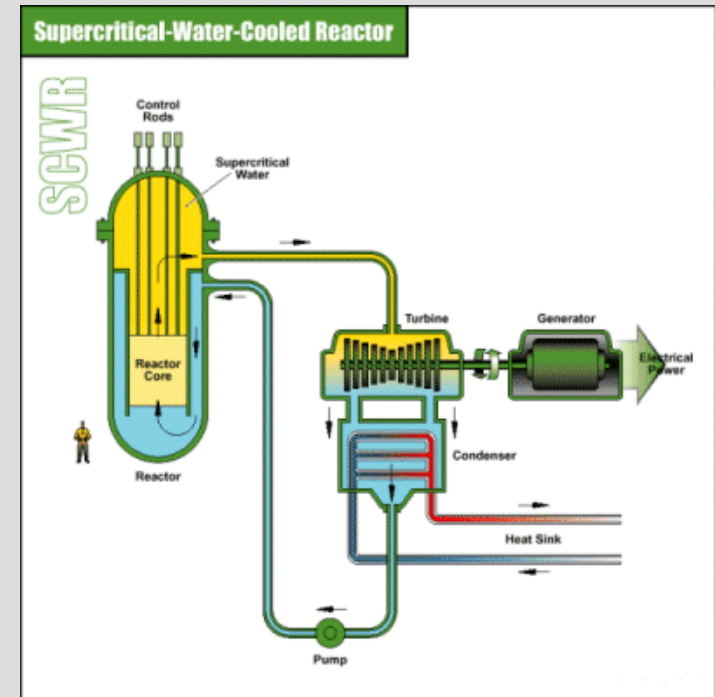
Characteristics of Next Generation Reactors

► Supercritical-Water Cooled Reactor

- 510°C; 1700 MWe
- Thermal or Fast Spectrum
- Actinide Management

► Fuel Characteristics

- Uranium Oxide
- Composite Ceramic Fuel
- MOX



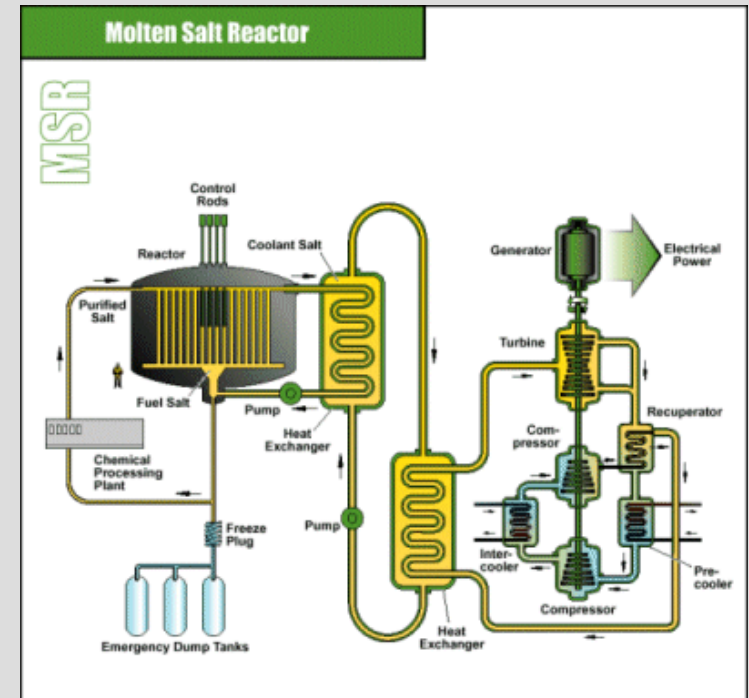
Characteristics of Next Generation Reactors

► Molten Salt Reactor

- 700°C; 1000 MWe
- Efficient Burning of Plutonium and Minor Actinides

► Fuel Characteristics

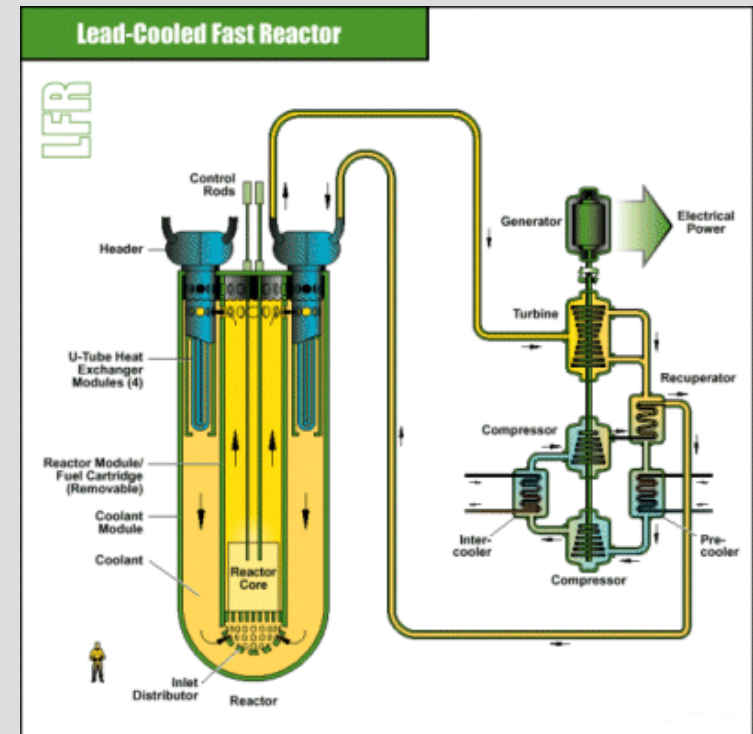
- Liquid Mixture of Sodium, Zirconium, and Uranium Fluorides
- Avoid Need for Fuel Fabrication



Characteristics of Next Generation Reactors

- ▶ **Lead-Cooled Fast Reactor**
 - Pb or Pb/Bi Coolant
 - 550°C; 300 to 400 MWe
 - Efficient Conversion of Fertile Uranium and Management of Actinides
 - Waste Minimization

- ▶ **Fuel Characteristics**
 - Metals or Nitride Fuels
 - Long Refueling Interval (15 – 20 yrs)





Traditional Fuel Development Schemes

- ▶ Fabrication of Initial Batch of Fuel
- ▶ Reactor Irradiation Testing
- ▶ PIE to Analyze for Fuel Performance
- ▶ Acceptance Criteria for Initial Batch
- ▶ Fabrication of Larger Sample Batch for Irradiation testing
- ▶ Lead Assembly Testing
- ▶ Approach is Lengthy and Costly (>15 yrs)
- ▶ Very Empirical



Elements of Advance Fuel Behavior Modeling

- ▶ Irradiation Damage
- ▶ Fission Gas Build Up and Release
- ▶ Interfacial Effects
- ▶ Thermomechanical Stresses
- ▶ Thermophysical Properties
- ▶ Chemical Effects
- ▶ Solid Fission Products



Summary- Modeling Benefits

- ▶ Flexibility to design specific fuel matrix
- ▶ Reduction in fuel development cost
 - Elimination of multiple testing
 - Design of fundamental experiments
- ▶ Development and fabrication of higher performance fuel matrix (e.g. higher burnup)
- ▶ Verification of fuel models
 - Enhancement in understanding of physical processes
 - Evaluation of uncertainties and sensitivities
- ▶ Advance methods for modeling complex physical and chemical effects



Summary - Modeling Benefits

- ▶ Inherent safety
- ▶ High efficiency – Durability and lifecycle performance
- ▶ Minimal rad waste using advance separation processes and waste forms
- ▶ High degree of proliferation resistant fuel matrix
- ▶ Physical security